David Sarnoff Research Center

Subsidiary of SRI International

CERAMIC/METAL COMPOSITE CIRCUIT-BOARD-LEVEL TECHNOLOGY FOR APPLICATION SPECIFIC ELECTRONIC MODULES (ASEMs)

Contract No.: DAAB07-94-C-C009

TECHNICAL REPORT

PERIOD: September 15, 1996 Through December 14, 1996

Sponsored by:
- Advanced Research Projects Agency
- Electronic Systems Tech. Office
- Application Specific Electronics Module Program
- ARPA Order No. A840
- Issued by U.S. Army CECOM under contract No. DAAB07-94-C-C009

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Prepared By December 11, 1996

Approved By December 11, 1996

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TABLE OF CONTENTS

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The David Sarnoff Research Center hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. DAAB07-94-C-C009 is complete, accurate, and complies with all requirements of the contract.

Date: 12/11/96

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Section I
WBS Task 2.1: Technology Transfer to Merchant Suppliers

A. TASK OBJECTIVE

Transfer the LTCC-M technology to a merchant circuit supplier, Dielectric Laboratories Inc. (DLI). This task will require a steady supply of several custom glasses that were developed during the Phase 1 program. One or more glass producers will be qualified to supply materials to the David Sarnoff Research Center or its designee to produce LTCC-M circuit boards and packages. The Phase 1 technology will be interactively transferred to DLI, who will be qualified by the fabrication of test structures and technology demonstration modules. During this transfer DLI will faithfully reproduce the LTCC-M processes that have been already implemented at Sarnoff.

B. INTRODUCTION

In July, 1995 a Technology Transfer program was begun between Sarnoff and Alcoa Electronic Packaging Inc. However, on December 21, 1995 Alcoa announced its intention to exit the ceramic packaging business. In the ensuing months the effort with Alcoa was wound down, and Dielectric Laboratories Inc. was identified as a company qualified to accept an LTCC-M technology transfer and become a merchant supplier of LTCC-M packages and substrates to commercial and military end-users. This ASEM contract was modified on July 16, 1996 to begin the Technology Transfer to Dielectric Laboratories Inc. Based on comments from the Technology Transfer to Alcoa, a number of material improvements have been incorporated into the transfer to DLI. This past quarter marked the end of the LTCC-M technology training sessions held at the David Sarnoff Research Center; and the implementation of a significant portion of the single-sided LTCC-M technology at DLI. The technology transfer to DLI is moving steadily along, with the principal schedule slips related to late delivery of several major pieces of equipment and the overall process of becoming familiar with new pieces of equipment.

C. TECHNOLOGY TRANSFER TO DIELECTRIC LABORATORIES INC.

Green Tape Casting

Due to the time constraints on this program. DLI decided to have the tape cast by an outside supplier, Richard E. Mistler. Several development lots of tape were prepared by Mistler prior to casting the first production lot. This was done to give Mistler the opportunity to learn how to cast the Sarnoff tape formulation. Thus far two 75 foot lots of tape have been made and evaluated. Both lots of tape behaved differently when processed at Sarnoff compared to DLI. They also behaved differently from tape cast by Sarnoff in small lot sizes. These differences were thought to be due to problems at Mistler. We believed that Mistler was improperly dispersing the slip before casting. This problem was addressed with the second lot of production tape and this lot is acceptable, but still not optimal. Differences have been noted between tape manufactured using Sarnoff KU14 and KU6 and the same materials supplied by DLI. An experiment is underway to determine which ingredient is causing the differences. One issue still remaining is the thickness of the tape. Mistler claims that they can not get better than ±10% thickness consistency across the tape. This is ±1.6 mils on an 8 mil thick tape. For microwave applications this may not be acceptable.

Metal Core Preparation

A great deal of time was spent these past three months at DLI to address problems related to plating. The visual appearance of parts plated at DLI was different than parts plated at Sarnoff. On DLI parts the plating was smooth with no visible grainy structure. In addition, the metal cores appeared black when removed from the Woods Ni strike bath, and it took much longer to plate parts to the proper oxide thickness. Since DLI was having problems in other areas, it was felt that these plating differences were causing the problems. Some of the problems encountered were that the metal core did not plate to a uniform green color and Ni oxide adhesion to the core was poor. Problems were also encountered when firing the MC6 ink, the cofired tape adhesion to the core was not good, and bright yellow areas occurred at the edge of the glaze after cofiring. These issues will be covered in later sections of this report. Sarnoff personnel visited DLI and we worked together to solve the plating issues. We discovered that the "poor" plating was due to a contaminated Woods Ni strike. After changing the bath, the plating became silvery and bright metallic. The plating times also became more typical of Sarnoff plating times. Finally, cores exhibited the same grainy structure seen on Sarnoff plated cores. At this time we also believed that the smooth plating surface was due to excessive agitation in the plating bath that was effectively polishing the surface of the Ni plating. As a result of the above evaluation and changes made in the plating process, DLI plated parts visually looked the same as Sarnoff plated parts. In the last two months DLI also determined that the difference in plating appearance was not causing any of the subsequent process problems that were experienced. At this time, plating problems have been resolved and plating is no longer considered to be an issue. In the past several weeks, DLI also successfully established a procedure for plating two cores at the same time, and for processing cores in 6" X 6" formats.

This past quarter, DLI developed a metal core deburring process and demonstrated that good product be can produced using these deburred cores. DLI also developed a source for EDM machining of the metal cores. A vendor, Intricut, successfully machined cores to the Raytheon specification. These parts were visually good and no deburring was needed before plating.

Thick Film Ink Formulation and Printing Cell

As with the green tape, DLI chose to have inks manufactured by an outside vendor because of the time constraints of the program. The manufacturer chosen was Heraeus Cermalloy. Conductors and glasses were sent to Heraeus along with manufacturing information from Sarnoff. The first inks received were evaluated by both Sarnoff and DLI. Sarnoff compared the materials to the Sarnoff-made inks, while DLI evaluated the materials on a use basis. Table I.1 shows the status of Lot 1 inks. Typically, the inks made by Heraeus had lower viscosities then similar inks manufactured by Sarnoff. When tested at DLI, the materials were found to be usable but not optimized. The one ink that needed the most change was Via 253. DLI and Sarnoff held discussions with Cermalloy and changes were recommended to improve this ink. Since this is a critical material, we sent Cermalloy enough additional silver powder and glass to make several iterations of the Via 253. The first iteration had an increased viscosity and appears to work. A second lot is being made in an attempt to increase the viscosity further. BC-103, TC-12, MC-6, BX-M141-6SC and LN1 were all made and are acceptable on a first time basis. We also recently received Glaze A, Via 2B and BX-M141-SC and are in the process of evaluating them.

The AMI printer was received and training was initiated with DLI personnel on processes not standard at DLI, such as via filling. DLI personnel were given training on using the vision system. This training will continue as DLI personnel move up the learning curve. DLI identified a Sarnoff 36 hole test pattern to use to make the Ground Via Contact, Plated Top Metal, and LTCC-M feedthrough deliverable samples. Screens, to build these parts, were ordered and received. Tape was punched for these parts by Sarnoff. No problems were encountered in printing on the cores or the tape. DLI successfully filled the vias in the tape with Via 253 ink.

Table I.1: Evaluation of Thick Film Ink (Lot 1 from Heraeus)

Ink	Printing Characteristics	Fired Properties
BC-103	Satisfactory	• Compatible with tape and Via 253
Via 253	– Viscosity low – Coats and does not fill vias – Via bump build-up incomplete and non-uniform	• Compatible with tape, BC 103, & TC-12 • Electrical continuity good • Bump height normal
TC-12	Satisfactory	• Compatible with tape and Via 253
MC-6	Satisfactory	• Compatible with core and bonding glaze
BX-M141-6 SC	Satisfactory	• Fired film appearance normal • Compatible with core
LN-1	Satisfactory	• Compatible with tape and TC-12 • Discolors ceramic slightly

Lamination and Precision Cavity Processing Cell

A lamination process was established at DLI to match the Sarnoff process as close as possible. Copper lamination blocks were received and gave improved results over earlier laminations using stainless steel blocks. The copper distributes the heat more uniformly. A new Carver four-post press was received and is operational. A low pressure gauge was purchased and added to the press to give more accuracy in the low pressure range used for this program. The press itself was calibrated using a pressure gauge placed between the platens. This insures that the actual pressure (as opposed to gauge readings) being applied to the tape during lamination is known. Pressures were based on data supplied by Sarnoff.

The tape blanking die and the punch and die set for the Raytheon part were received and evaluated. The results were good, and no problem was encountered when the vias were filled. DLI also received the Raytheon cavity punch from Sarnoff, and evaluated the tool and the process to make the Raytheon part at DLI. Tapes were laminated into sections, and each section punched to form the two cavities. The sections were laminated together, and then colaminated to a Raytheon EDMed core. The part was fired and the structure inspected. The cavity side walls were well adhered to the core and tape, and the resultant part was visually good. Based on this initial evaluation, it appears that DLI will be able to fabricate the Raytheon C-Band Amplifier packages.

Firing Cell

The majority of the effort this past quarter went into establishing the furnace profiles. The glazing profile was relatively straightforward to set up, and the results on the fired BX-M141-SC glaze were good. The glass fired very similar in appearance to the way it looks when fired at Sarnoff, and no changes were made to the profile after the initial setup. The next profile DLI tried to establish was the oxidizing profile. Even after matching the DLI furnace profile to that established by Sarnoff, DLI continued to experience problems with both oxidized cores and fired contact ink, MC6. After oxidation of blank cores, round yellow flecks of a glassy material can be observed on both the top and bottom of the metal core. This material can be easily removed; exposing the plated core. Sarnoff occasionally sees this same defect, however not as extensively as DLI. This issue will be further investigated at a later date. Bright yellow areas on both the top and bottom of oxidized cores and regions of color variations (ranging from yellow to light green) can also be observed. These defects are not acceptable. These areas can be quite large and result in regions where the oxide flakes off the core. This occurs mostly on the bottom side of the core where the oxide is stripped anyway, later in the process. The problem with firing MC6 is that the fired conductor turns the tape yellow and the metal itself looks nothing like the material does when fired at Sarnoff.

Based on experiments run both at DLI and Sarnoff, it is believed that one of the causes of the oxidation problem is low air flow in the furnace. DLI was able to make a series of adjustments in the Lindberg that increased the air flow from 300 SCFH to over 700 SCFH so that it is now very close to the air flow in the Sarnoff furnaces. This resulted in significant improvements in the oxidation of the core. DLI also discovered that increasing the peak firing temperature resulted in a significant improvement in the oxidation process. As part of a test at DLI, a core was oxidized in the DLI production Watkins Johnson furnace set at a peak of 850°C. The part was visually very good after oxidation. This led DLI to increase the peak firing temperature in the LTCC-M Lindberg furnace. When the temperature of the Lindberg furnace was increased the same improved results were observed. There was reduced color variation, glassy flecks, bright yellow areas and flaking oxide. In addition, the MC6 fired very nicely. There was no sign of contamination and the metal was typical of what is observed after firing at Sarnoff. Based on these results, a oxidizing temperature 25°C higher than the original peak was selected. Once the MC6 was shown to properly fire, a number of 36 hole test parts, with up to three layers of filled, stacked vias, were fabricated. After firing, the electrical continuity of all vias to the metal core was verified, demonstrating that good contact is made from the MC6 through the oxide to the metal core.

The combination of increased air flow and higher oxidation firing temperature has minimized, but not eliminated, the glass flecks and the bright yellow areas on the core. Further evaluation of the yellow areas indicate that there may also be a cleanliness issue. Many of these areas look as if they are fingerprints. Future efforts will address the DLI handling process.

The next furnace profile addressed was the cofiring profile. The first problem associated with this profile was that tape, fired on cores, did not adhere to the glaze and lock-in did not occur. In addition, yellow areas in the glaze, adjacent to the edges of the fired tape were observed. DLI originally believed that the yellow color was causing the poor adhesion and lock-in problem. As the oxidation profile improved, it was discovered that the adhesion problems just discussed were due to poor oxidation of the core. Once the oxidation improved, the yellow color disappeared and subsequent fired parts had good adhesion and lock-in.

After solving this problem, other firing issues were addressed. It was noted that tape fired at DLI on metal cores was consistently dished, while the same tape fired at Sarnoff resulted in less or no camber, and was typically domed if camber was present. In addition, DLI was not able to adjust the camber at DLI by changing the peak firing temperature. To understand this, two possible causes of the problem were invistigated. One was the lamination pressures used to process the tape and colaminate it to the core, and the second was the firing profile. DLI shipped their pressure cell to Sarnoff so they could measure their actual pressures. It was discovered that DLI was not compensating the Sarnoff readout pressures for the zero pressure offset. Conversely, this meant that DLI was laminating at higher pressures than appropriate. A quick experiment was run at DLI using lower lamination pressure, showed a reduction the amount of camber compared to similar parts processed at higher pressures. Lamination temperature is another process variable which may be different between the two companies. Additional tests will be run to verify and quantify these variables next month. The firing profile will also be investigated in much greater detail in the coming month to see whether changes in either the peak temperature and/or time at temperature can effect the camber.

Freestanding tape samples were prepared to measure electrical properties. It was found that Mistler tape fired either at Sarnoff or DLI has poorer electrical properties than ABT (Sarnoff cast) tape. Also, the same tape fired at Sarnoff has consistently better electrical properties than when fired at DLI. A resonant cavity was used at DLI to measure Q and K. Typically, Sarnoff fired tape has Q values around 1000, while similar material fired at DLI comes out around 750. These problems were originally, attributed to problems with the Mistler tape, but may be a combination of both material or process variations. There appears to be a difference between the glasses supplied to Mistler by DLI and the glasses purchased by Sarnoff. This variable is currently being evaluated in a matrix experiment at Sarnoff, and will be completed in the next few days. Second, it is believed that, as noted above, there may be a firing issue that is giving DLI consistently lower electrical problems. This will be evaluated at the same time the effect of firing on camber is investigated. Finally, the lamination process may also be contributing to the variation in electrical properties, since a thickness variation across the fired sample has been observed.

Top Conductor Plating Cell

DLI has successfully demonstrated that the top conductor of a fired LTCC-M part can be electrolytically plated. The Sarnoff 36 hole test was used for this purpose. Parts were built with up to three layers of tape containing filled stacked vias and TC12 top conductor. After firing, all parts made were probed for electrical continuity and found to be good. The oxide was then stripped from the metal core and the part plated. A visual inspection of the first plated conductor on parts showed attack of some metal pads as a result of the plating process. Additional efforts have improved the process and the amount of attack on the pads has been reduced.

2-sided Metal Core Feedthrough Cell

The technology transfer training sessions related to this area were completed this quarter. A local printed wiring board manufacturer supplied DLI with metal cores having holes drilled in them using the 36 hole test pattern. The holes were inspected and are visually acceptable. The holes were then deburred, plated and oxidized with good results.

Deliverables

The following deliverable items were sent to Sarnoff this past quarter:

1. Two green tape lots from Mistler (one of these lots, BDLS-1, has been judged to be unacceptable by Sarnoff)
2. Plated Cu/Mo/Cu Core Samples
3. LTCC-M Fired Samples
4. Ground Via Contact Samples
5. Top Metal Plated Samples

Summary

All technology transfer training sessions were completed. Tape made by Mistler and thick film inks made by Heraeus are generally acceptable but additional work needs to be done to optimize them. All metal core processing, such as machining, through hole forming and plating are working well. Lamination was identified as a possible cause of camber on fired cores and tests are currently ongoing to verify this and identify the variables. Firing was a big problem this past quarter, however, all tempeature profiles and air flow parameters have been adjusted to produce better parts. Additional work still needs to be done with the cofiring profile to optimize it. Top conductors on test parts were successfully plated and this process also appears to be acceptable.

D. PLAN FOR NEXT QUARTER

- Evaluate (at DLI) the impact of peak firing temperature on both camber and the electrical properties of the tape
- Evaluate (at DLI) the impact of lamination pressure and temperature on the camber of the tape fired on to the core
- Optimize the next lot of tape from Mistler
- Evaluate the next lot of Heraeus thick film inks
- Build and test 20 samples of the Microwave Power Amplifier Technology Demonstration Vehicle
- Build and test 2 samples of LTCC-M with feedthroughs

Section II
WBS Task 2.2: Customize LTCC-M for Specific Applications

A. TASK OBJECTIVE

Extend the LTCC-M technology to meet any requirements of the technology demonstration modules, and any general packaging trends of the electronics industry.

B. INTRODUCTION

Progress is reported for the extension of LTCC-M to higher density circuits. To increase the circuit density of LTCC-M substrates, thick film inks have been developed that can produce test structures having 4 mil diameter vias and 3 mil lines and spaces. To fabricate high density circuits in a cost effective manner, it is important to utilize large area processing, and then singulate the circuits near the end of the fabrication cycle. A robot assisted method has been designed and is presently being set-up. LTCC-M cavity technology is being extended and hermetic sealing processes are being developed. To demonstrate the compatibility of LTCC-M to low cost, miniature high density packages, a compact Ball Grid Array (BGA) package will be designed and fabricated.

C. OPTIMIZE CAVITY PROCESSING FOR LTCC-M TECHNOLOGY

Progress is reported for the extension of LTCC-M cavity technology for packaging in the following areas: 1. Embedded cavity structure optimization, 2. Internal vapor analysis of a fired embedded cavity, and 3. Hermetic sealing of the cavity.

1. Embedded Cavity Structure Optimization

Background

Fired parts containing embedded cavities were demonstrated for this program in the previous quarter. Defects were periodically observable involving ceiling sag, sag leading to ceiling rupture, or cavity sidewall bellowing. A study of the processing variables was made in order to eliminate the aforementioned defects. In addition to the goal of cavity structural integrity, obtaining accurate cavity dimensions is important for device considerations, such as buried connectors leading to a microwave resonator device contained in a cavity.

Objective

Develop a process for successful reproducible generation of defect-free embedded cavities for the LTCC-M based system.

Approach:

A number of experiments were run to meet the objective. The number of multilayers comprising the ceiling of the cavity or the cavity itself were varied. The multilayer construction was laminated at 185°F according to one procedure. 3" x 3 " stacks were laminated with 3,000 lbs. pressure. Stacks, designated for use as cavity layers, were punched after lamination. Co-lamination of stacks was done at 1,000 lbs. pressure. Final co-lamination of the assemblage to a Cu/Mo/Cu metal core was done at 500 lbs. pressure. Co-firing of the Cu/Mo/Cu metal core and layers of ceramic tape was done with the standard firing profile.

The results are tabulated in Table II.1. Note that one part is further referenced to Figure II.1, which shows a cross-sectional view of an embedded cavity.

Table II.1: Embedded Cavity Test Results

Part ID	Part Construction (No. of Ceramic Layers)			Fired Part Observation
	Ceiling	Cavity	Floor	
081996-i	4	4	2	minor ceiling sag
081996-ii	6	4	2	straight ceiling (ref. Figure II.1)
090396	1	4	4	ceiling sag and rupture
090496	2	2+4+4	0	ceiling sag and rupture
090596	2	4+4+4	0	ceiling sag and rupture
090696	2	2+2+2	2	ceiling sag and rupture
090996	2	4	2	straight ceiling
091196	2	4	2	straight ceiling

Summary

From the limited number of experiments, it is noted that deep cavities were not possible to form with 2 tape layer ceilings regardless of cavity height (6, 10 or 12 layer). Cavities were successfully made of 4 tape layer height with 2, 4, or 6 layer ceilings (see Figure II.1). In summary, cavity height should be no more than 4 tape layers thick (greater heights appear problematic) with ceiling thicknesses of 2 layers.

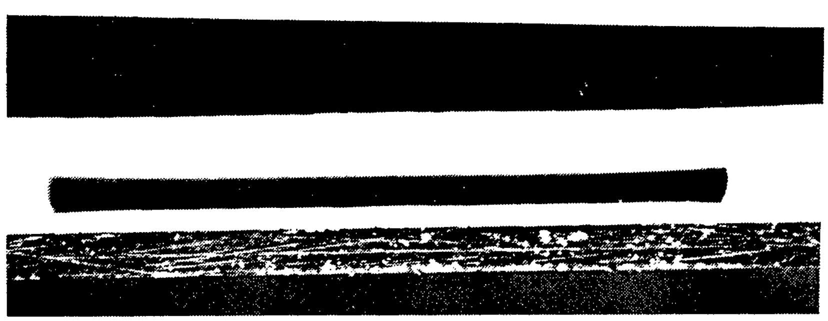

Figure II.1: Cross section of an embedded cavity (4 layer cavity height, 6 layer ceiling, 2 layer floor, on a Cu/Mo/Cu metal core)

2. Internal Vapor Analysis of Fired Cavity

Background

Cavities are designed to contain functional elements. Therefore it was important to resolve the composition of trapped gas after co-firing a multilaminate containing buried cavities.

Approach

A sample consisting of a 2 tape layer ceiling, 4 tape layer cavity, and 2 tape layer floor was prepared and co-fired on Cu/Mo/Cu metal. Trapped gas was analyzed using Internal Vapor Analysis (IVA) technique by Oneida Research Services (Whitesboro, NY).

Results

IVA was performed using a rapid cycle mass spectrometer. After the sample received a 12 hour prebake at 100°C, it was sealed against the inlet of the spectrometer. Two cavities were separately tested by puncturing the two layer ceiling. A pressure rise in the chamber was detected in both cases and the gases detected were those seen in air.

Summary

The buried cavities in the laminate contained air and no traces of hydrocarbons. The positive pressure upon piercing through the two layer ceiling indicates analysis was that of trapped gas.

3. Cavity Enclosure by Sealing of Lids

Background

LTCC-M packages will require the sealing of lids to cavities as an assembly step. A goal was set to develop processes that resulted in hermetic sealing of lids-to-packages. For temperature requirements, both the higher temperature frit seal and lower temperature solder seal types were investigated. The goal was to seal lids to pre-formed cavities in LTCC-M substrates without circuitry.

Approach

Packages without circuitry were fabricated with cavities. Five layer laminates were punched using the AMP punched hole die press to create 2 mm square cavities. It was these cavities which were to be capped with a lid-to-package seal by both frit and solder techniques.

Sealing Glass Technique

Several frit seal candidates were screened for wetting and flow on ABT-52 ceramic. A candidate selected as promising was mixed as a thick film glaze for purposes of screening frames around punched cavities. All frit candidates were initially selected to closely match the thermal expansion coefficient of fired ABT-52 (56×10^{-7}/°C). Sealing parameters, that were not provided by the frit manufacturer's specifications, were determined by measuring the melting point using differential scanning calorimetry (DSC).

In addition to the thick film glaze approach, ceramic lids with framed glass frit preforms were evaluated for sealing to ABT-52 ceramic. These lids were obtained from an outside source and materials specs were not provided. The glass frit was scraped off, collected, and characterized by DSC.

Frit seal candidates for thick film glaze were screened by heating small quantities of powder on ABT-52 ceramic to specified temperature and time schedules for sealing as provided by the frit manufacturer. Candidates were characterized qualitatively for wetting and flow. The results are provided below in Table II.2.

Table II.2: Sealing Glass Frit Screening Test Summary

Glass Code	Glass Type	Sealing Temperature (°C)	Sealing Time (min.)	Wetting and Flow on LTCC
7555	Lead borate (Vitreous)	450	15	poor
7556	Lead borate (Vitreous)	450	12	slight
7575	Lead zinc borosilicate (Devitrifying)	450	60	poor
7585	Lead zinc borosilicate (Vitreous)	415	10	very good
7589	Lead zinc borosilicate (Devitrifying)	480	15	poor
7599	Lead zinc borate (Devitrifying)	425	45	poor

Of the candidates tried, glass code 7585 exhibited the best wetting and flow on ABT-52. The frit was mixed in a thick film glaze composition which contained acrylic based resins. Test firings of the glaze mix showed incomplete binder burnout. Insufficient burnout will cause porosity in the seal due to outgassing of trapped organics from the vehicle. Insufficient burnout also caused the high lead oxide glass to darken due to reduction of the lead oxide to metallic lead. A different dispersant vehicle was used to replace the organic responsible for the incomplete burnout. Test firing of this glaze resulted in no residue.

The DSC melting point of the frit collected from the framed preforms of supplied ceramic lids was 490°C. This system and the 7585 glaze produced a slight yellow color in the resulting glass which is characteristic of lead-base glasses. The DSC melting point temperature will be used in the sealing the supplied lids to ABT-52. Sealing operations will be carried out in an oxidizing atmosphere to prevent reduction of lead oxide. The lids which will be used in 7585 glaze tests will also be those of the drawn ceramic (0.5 cm square) supplied by an outside source. The thick film glaze will be applied to lids previously scraped clean of the 490°C melting point material.

Solder Sealing Technique

Metal alloy solders are desirable in packages such as the C-band package. The Sn 63 / Pb 37 solder, with its melting point of 183°C provides for low enough sealing temperatures to ensure no movement of components in the process. Work has started in the solder sealing of the AMP package. The plan is to print flux-containing Sn 63 / Pb 37 solder on an AMP package and then carry out a solder operation using a specially prepared metal lid (explained below). The AMP package will be first processed by the typical firing of silver top metal followed with coating of Ni/Au plating. Solder will then be printed to frame a selected area. This configuration will then be ready to accept the specially prepared metal lid for the solder sealing operation. The metal lid will be Cu/Mo/Cu plated with Ni and a light Au flash. Since solder wicking is anticipated for uniformly plated lids, a patterned lid plating step will be developed where a mask defines placement of the Ni/Au. This should reduce wicking of the solder away from the lid-package interface thereby helping to produce a hermetic seal.

Analysis

Analyses of the hermeticity of seals made from both the frit and metal alloy solder techniques will be made using gross leak testing methods (Oneida Research Services, Whitesboro, NY).

D. HIGH ADHESION TOP CONDUCTORS

Background

With the proliferation of mass consumer electronics, the need for new packaging solutions has become apparent. The trend towards smaller integrated circuit geometries and the progress towards smaller, less expensive products has created demands of electronic packages which established technologies cannot satisfy. The dual in line package (DIP), the industry bulwark for years, is quickly reaching its practical limits in terms of lead pitch and I/O count. The DIP becomes physically cumbersome at I/O counts as low as 64 making it hopelessly impractical for applications requiring hundreds of I/O's. The future needs of the industry as size decreases and power increases are: ever increasing I/O counts, decreasing lead pitches, multilayer and multichip packages, and improved power dissipation capability (internal heatsinks or heatspreaders). Almost all packages commercialized to address these issues suffer some limitations. The ball grid array (BGA) package satisfyies many of these needs, and BGAs are rapidly gaining popularity.

The ceramic BGA has solder ball I/O connections spread over the surface area of the substrate, making very large I/O counts possible. Solder ball I/O's are inexpensive and offer several attractive features, namely self-alignment and reworkability. The ceramic substrate (alumina is common in industry) contains a die cavity and an internal system of vias and conductors for connecting the chip to the solder ball I/O's. The goal of this project is to apply Sarnoff's experience in ceramic packaging to producing a low cost, high performance ceramic BGA package for use in temperature tolerant, small pitch, high power, high I/O count applications.

Design

Due to time and budget constraints, the design chosen for the current package was simple yet will be sufficient to demonstrate the compatibility of the LTCC-M Process with BGA production. A double array of 40 solder balls total around a square 130 mil die cavity is the basic premise of the design (see Figure II.2). The lateral dimensions of the package are 400 mils x 400 mils. Six such arrays are printed on each 3" x 3" LTCC-M substrate (see Figure II.3). Eutectic lead/tin solder was chosen due to its well known reflow characteristics. Solder pads are 20 mil circles at a 50 mil pitch. The solder ball height will be determined by the amount of solder printed on the pads. Vias 8 mils in diameter will provide the electrical connection from the solder balls through the ceramic to the metal base. Capture pads on the bottom of the ceramic and top of the metal base provide the electrical pathway through the metal ceramic interface (a glaze developed for the ASEM program). Conductor and via metallization are silver based inks developed for ASEM. The thickness of the ceramic is flexible and can be changed depending on the application. A schematic cross section of the package is shown in Figure II.4.

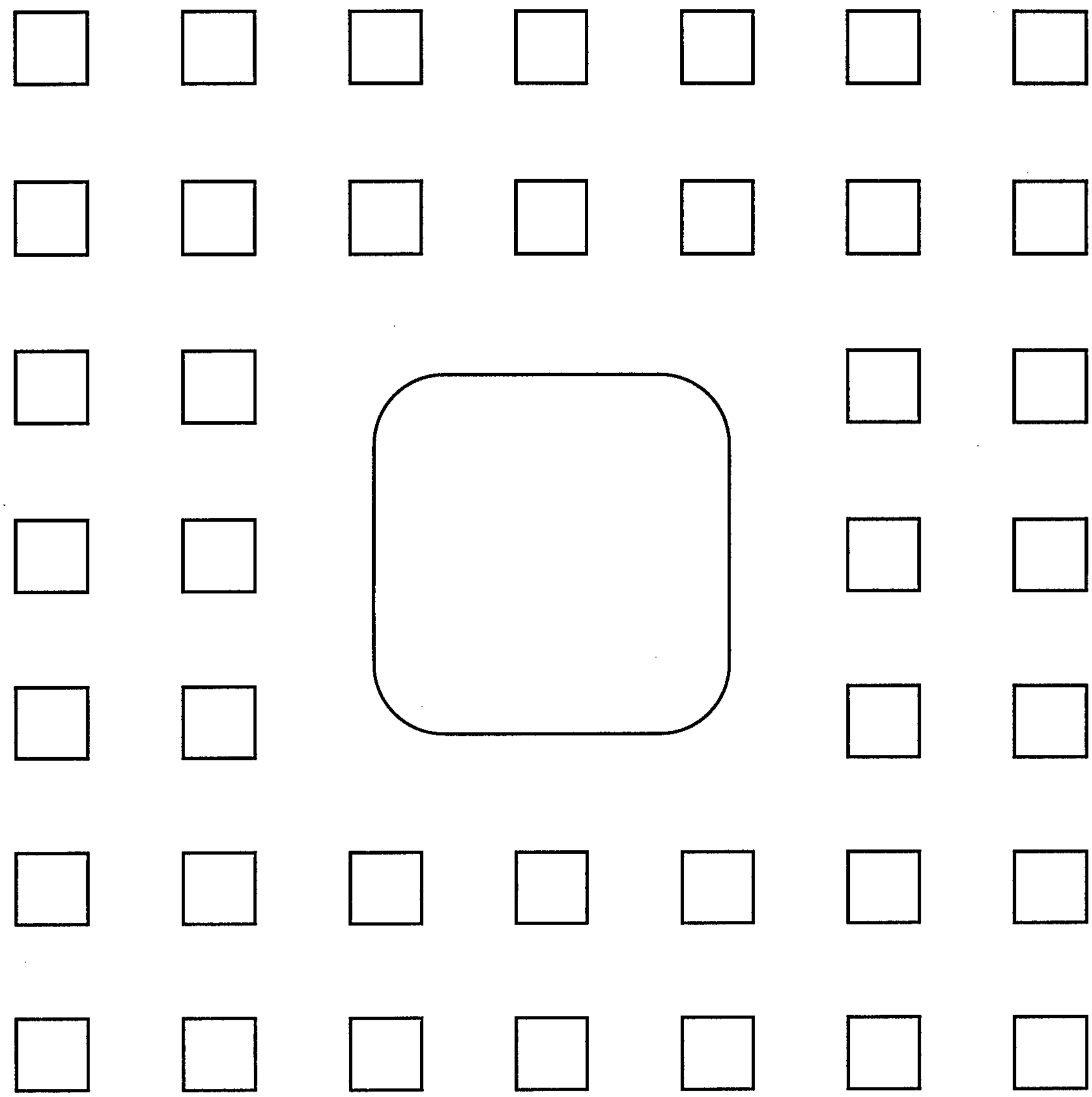

Figure II.2: Solder pad array and die cavity for LTCC-M BGA

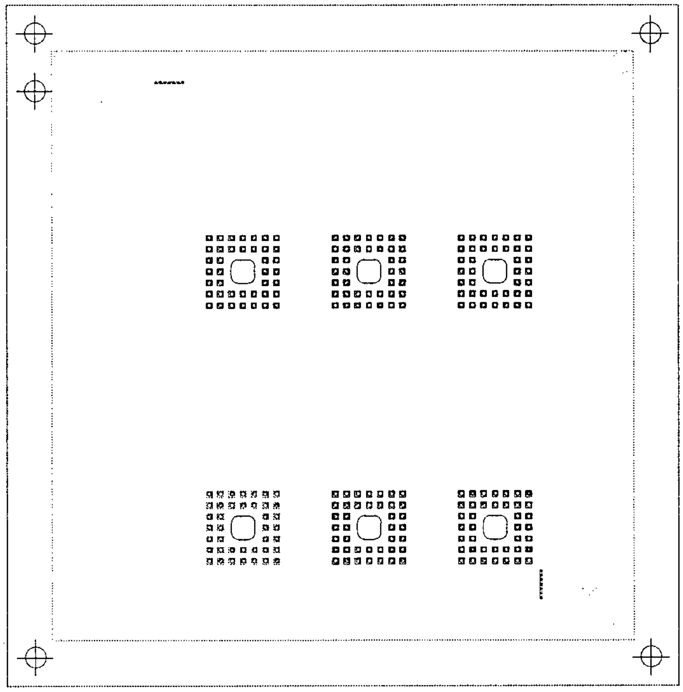

Figure II.3: Six BGA's on a LTCC-M substrate

A structure for testing the electrical integrity of the package has also been developed. A 1 in x 1 in glass plate with solder bumps corresponding to those on the package and thin film Ni/Au conductors leading to an array of probeable 40 mil solder bumps on the periphery will be used. Low expansion glass was chosen to facilitate alignment with the package for reflow. The self aligning nature of BGA's will also facilitate reflow.

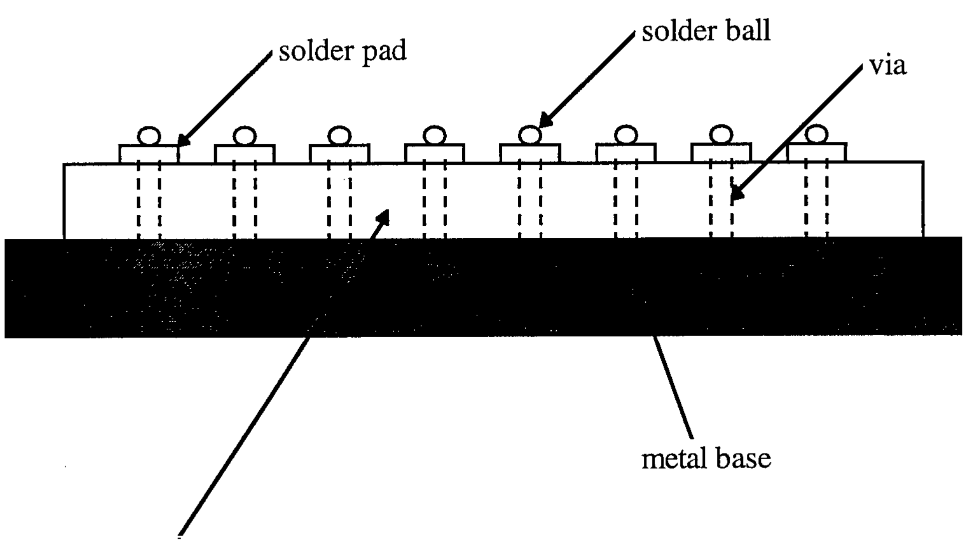

Figure II.4: Cross section of LTCC-M BGA package

Package Testing

Electrical integrity of the via-solder ball-conductor pad system will be tested by connecting the package to a glass test fixture and probing the circuit from the package base metal to the probe pads on the periphery of the glass fixture. It is fabricated by plating Ni bumps, pads and conductors followed by plating Au on the bumps and pads only. Special photomasks have been designed and ordered for this purpose. Solder paste will be screen printed on the bumps and probe pads, and then reflowed. For the test, the bumped glass plate will be placed over the BGA with the solder bumps aligned and the entire assemblage is reflowed. Each solder ball and via in the package will then be probeable through one of the probe pads on the periphery of the glass plates.

A separate test for solder ball adhesion is also being done. Two fired 3 layer ABT-52 on Cu/Mo/Cu laminates were prepared without vias or capture pads, only top pads were screen printed on the tapes prior to lamination. 36 pads were printed on each top surface one set having 20 mil diameters, the other having 9 mil diameters. The pads were then plated with electroless Ni/Au and solder paste printed over the pads. The solder will be reflowed and adhesion will be evaluated with a shear tester. A preliminary test was done with 20 mil pads on ABT-61 tape. Solder paste was manually placed on the pads and reflowed. The balls were then sheared about midway down. The fracture was through the solder ball and not the solder/pad interface, indicating good adhesion.

Progress

The package design has been completed and the arrival of all tooling is imminent. A total of 5 screens, 6 metal print masks, 1 injection stencil have been ordered for printing pads, solder paste and via filling. Four photomasks have been ordered for the plating of the test fixtures. Inks, solder paste, tape and plated Cu/Mo/Cu are in hand. Fabrication will begin as soon as screens arrive. Test fixture fabrication will begin when photomasks arrive. Photolithography and plating will be done in house.

Solder ball adhesion testing has already begun, as described earlier. Pads of 9 and 20 mils have been printed on ABT-52 tapes, firing and plating has been done and solder paste printed. Reflow and adhesion testing is to follow. A preliminary test with ~20 mil pads on ABT-61 tape has shown good adhesion. Once packages have been fabricated, thermal cycling/ fatigue testing will also be done. Finally, cavity caps will be used to seal the die cavity. These tasks will be completed in the final quarter of the project.

E LOW COST SINGULATION PROCESS

Background

A green tape singulation test-bed system is being developed to cut laminated green ceramic into individual packages, separate them and accurately place them on a Cu/Mo/Cu metal core. The parts are subsequently fired and then the metal core cut into separate parts. When the diced green parts are placed on metal core, gaps (or streets) are left between them to allow clearance for cutting the metal. This method of package singulation eliminates the need to cut the fired ceramic and metal core simultaneously. The system has been designed, most of the parts fabricated, and is currently being assembled.

Cutting Experiments

Simple tests have been conducted to investigate green (unfired) ceramic cutting techniques. Ceramic in the range of .010" to .070" thick has been used. A fixture which has a temperature controlled cutting blade has been fabricated and used in the experiments. Blades ranging from .003" to .025" thick and made of Stainless Steel and Cubic Zirconia have been evaluated.

When the ceramic is cut with an unheated blade, the ceramic "breaks" along the cutting line leaving an undesirable rough surface on the cutting plane. This is particularly evident on thick parts and with a thick blade. The quality of the cut improves with temperature with clean cuts starting to occur at 350-400°F. At lower temperatures, the ceramic will cut cleanly part of the way through the thickness, then break. The same behavior occurs if the cutting speed is too high, or the blade is too thick. It was observed that the thick blades benefited more from heating than the thinner blades. This may be due to a quenching effect. The blade is held in a heated clamp. As the blade makes contact with the cold ceramic, the blade is cooled. This effect is more pronounced in the thin blades. There is a trade-off in the thickness of the blade. The thin blades inherently cut cleaner, but have a higher temperature drop. The simple test set-up was not repeatable enough to select the optimum blade thickness, cutting speed and temperature, but has been useful in designing an accurate singulator. Clearly, the cutting must be done in a very controlled manner. Therefore, a precise servo mechanism will be used to both cut, pick and place the green tape.

System Description

The singulator is based on and Adept 550 table-top Scara robot. The Adept was selected because of it's speed, precision, flexibility and availability. It includes a 68030 based controller and motor power amplifiers which handles the joint kinematics. The controller is used to control the entire system, using analog and digital I/O to control air, and vacuum solenoid valves, temperature controllers, and a tool changer. The motion controller is programmed using a high level robotics language, V+. A hand mounted force/torque sensor is used to accurately control the cutting and placing forces. A side view of the robot mechanism is shown in Figure II.5.

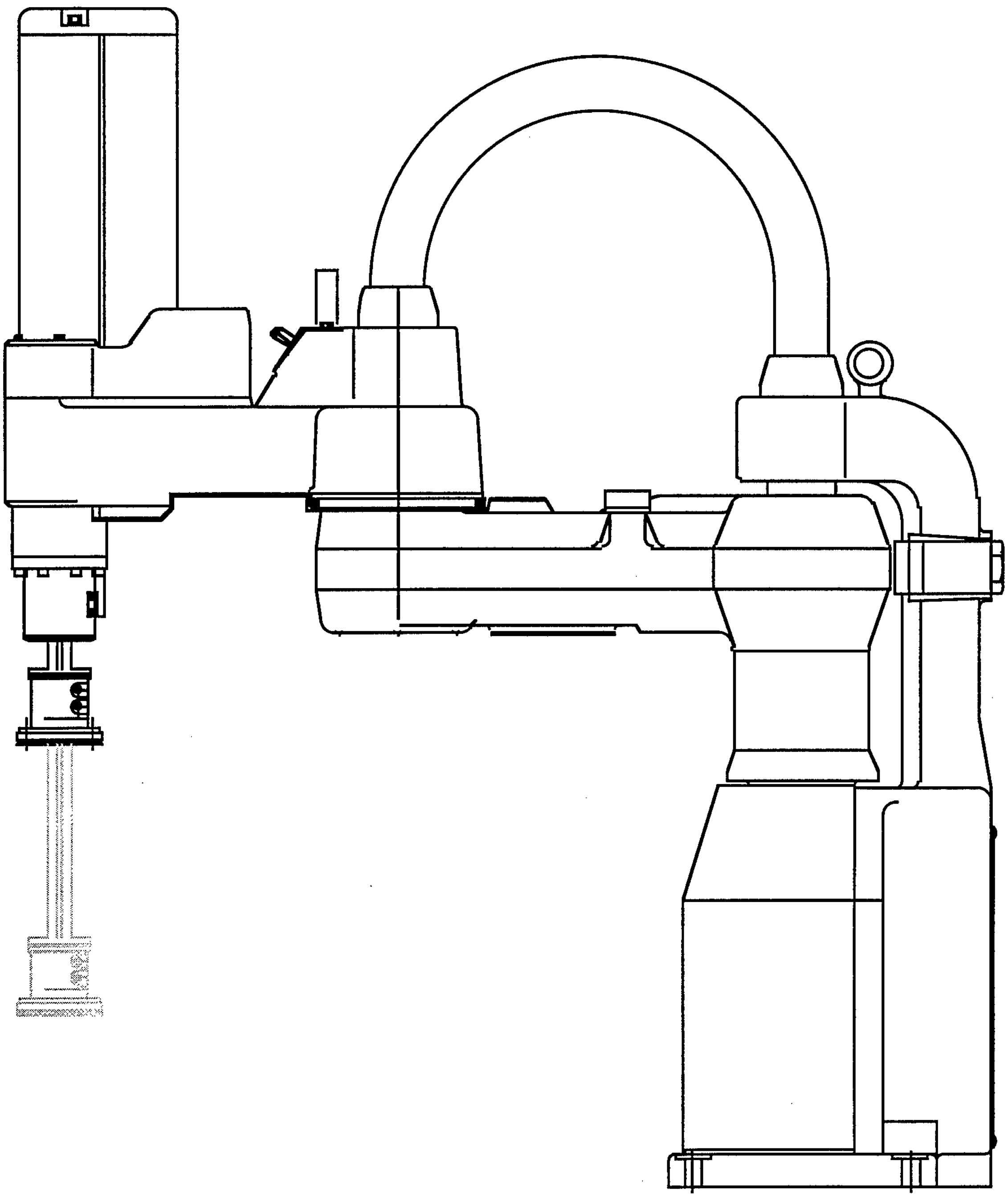

Figure II.5: Adept 550 table top robot arm.

The singulator has a vacuum chuck for accurately holding the green tape. The metal core is held by a similar vacuum chuck, located directly adjacent to the green tape. The robot hand is fitted with a tool changer which can grasp one of two tools; the hot knife tool and the vacuum picking tool. The tool changer passes both electrical power, signals, and pneumatic lines through to the tools. A top view of the robot workcell layout is shown in Figure II.6.

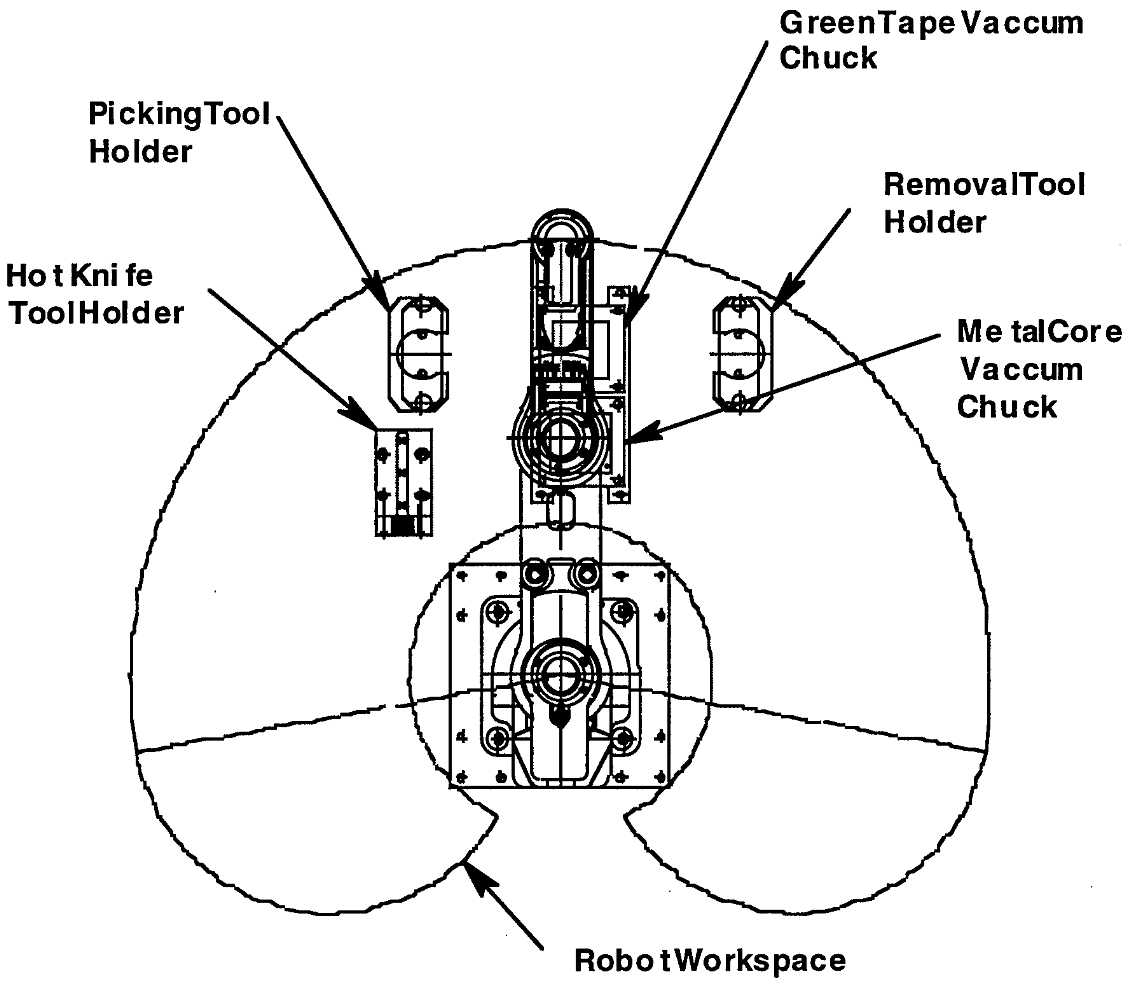

Figure II.6: Robot workcell layout.

Vacuum Chuck Design

Two vacuum chucks have been designed and fabricated for precisely locating and holding the metal core and green tape during the cutting and pick and place operations. An isometric view of the combined vacuum chuck assembly is shown in Figure II.7. Taper pins pressed into the top surface precisely locate the metal core and green tape laminate. The assembly is built on a common baseplate for accurate location of the two parts relative to each other. Calibration fiducial marks are machined into the centerline of each fixture. These marks were post-machined after assembly to assure accuracy. All components use alignment dowels, so relative position will be maintained if dis-assembly is required. The fiducials are used to calibrate the robot software locations for each fixture to allow accurate picking and placing of the cut parts.

The metal core fixture is a straight forward vacuum chuck, machined from brass. A grid of 0.150" vacuum holes are fed by the plenum chamber below. The vacuum supply fitting is located underneath. Vacuum is generated by a multistage vacuum ejector, for combined high flow rate and high vacuum level. The compressed air supply to the ejector is controlled by a solenoid valve which is commanded by the robot control software. Cartridge heaters are pressed into reamed holes close to the top surface to heat the metal core. The metal core is heated to soften the surface coatings so the green tape parts will stick well when pressed in place with the robot placing tool. A platinum RTD temperature sensor is used for temperature measurement. An auto-tuning PID controller maintains accurate temperature. The exact temperature will be determined experimentally.

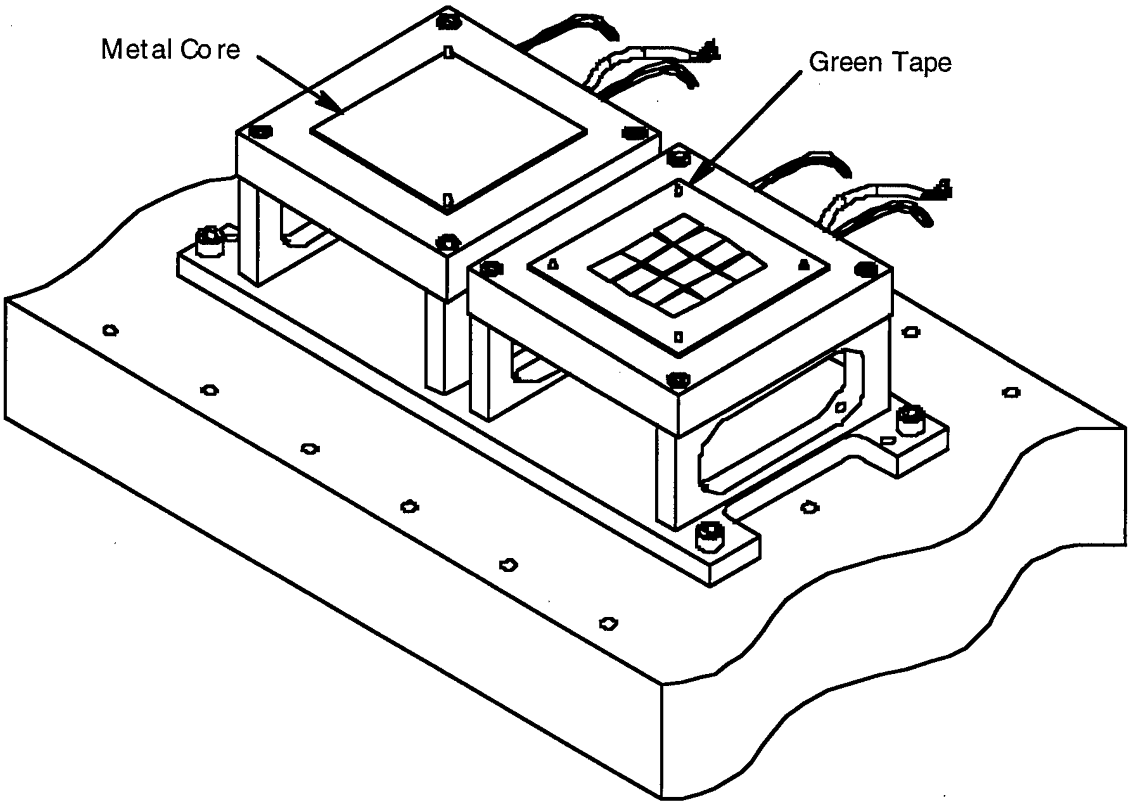

Figure II.7: Vacuum chuck assembly, isometric view.

The green tape fixture is a more novel design. The fixture initially holds the green tape in place during the cutting. A strong holding force is needed to prevent the taper of the knife from pushing the material away from the cut. If the material slides against the vacuum chuck surface, the alignment will be compromised. The fixture also holds the tape during the pick and place operation. As parts are removed, the vacuum surface is exposed thus partially venting the vacuum. Therefore, features have been designed into the green tape vacuum system to minimize this effect. The vacuum plenum is divided into 4 chambers with independent vacuum feeds, as shown in Figure II.8. Each vacuum feed has a check valve which closes when the plenum vacuum is vented. This prevents to excessive leakage as more parts are removed.

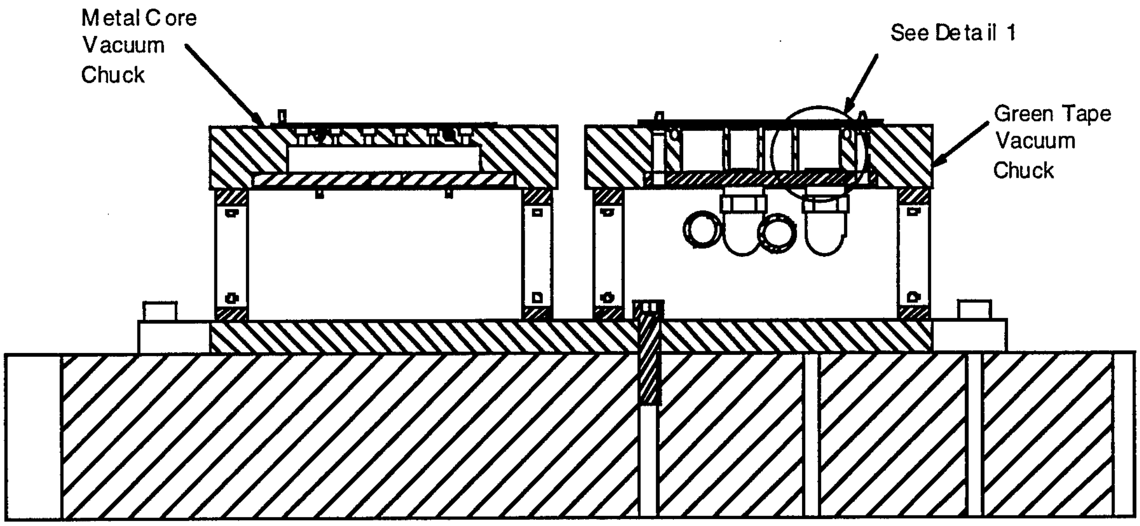

Figure II.8: Vacuum chuck assembly, front cross-section view.

Figure II.9 is a detail showing the vacuum orifice design. The orifice is a stepped hole 0.015" in diameter with a .078" diameter counter-bore. The small diameter on the plenum side prevents excessive leakage when the hole is exposed. The larger diameter at the surface provides a large area to generate the required holding force. The diameter must be small enough however to prevent the green tape from dimpling.

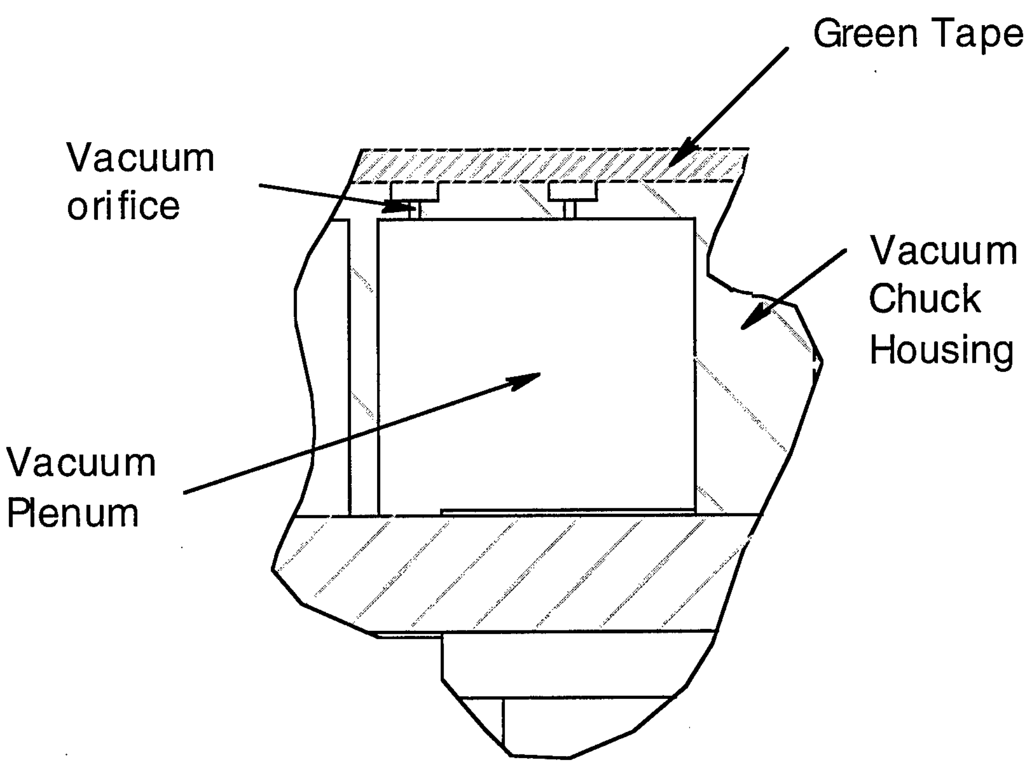

Figure II.9: Green Tape vacuum chuck assembly, detail view.

Robot End-Effector Tooling

The Adept robot hand is fitted with a 6 axis force/torque sensor with control electronics built into the motion controller. A robot is fundamentally a position controlled device. The force sensor allows accurate control of both position and force in cutting, picking and placing. The control software is being written with a guarded move during the cutting operation. The blade is lowered using position feedback, with an outer loop which monitors force. When a specified force is reached the blade stops and retracts. This gives very precise control of the cutting motion. A similar algorithm is used for pressing the LTCC-M material onto the metal core.

A tool changer is mounted on the force sensor to allow exchange of the hot knife and vacuum picker. The tool changer allows the same mechanism to be used for both operations, resulting in high accuracy with a minimum of complexity and cost. The changer passes air, vacuum, electrical signals, and power to the tools through internal connections. Positional repeatability of the exchange is better than 0.001". The tools are grasped and released using an air actuated mechanism controlled by the programmable motion controller.

The vacuum picker is a simple vacuum pad with a high ratio of vacuum area to overall area. This is to assure the part is pulled reliably off the green tape fixture. Vacuum is supplied through the tool changer.

Current Status

The major fabricated components, including the cutting and picking tools, vacuum chuck fixtures, etc., have been completed in Sarnoff's model shop. The robot base table has been installed. The robot, motion controller, and power amplifiers have been received. The tool changer components and computer monitor are expected by Dec. 9. Mechanical assembly is in progress. The controller, power amps, robot controls, temperature controllers, power supplies, solenoids valves and vacuum venturis are currently being installed in a 19" rack. Electrical wiring was started on 12/2/96 and installation of pneumatic lines began on 12/6/96. The system should be functional by the end of the year. Off-line software development is underway, but testing and debug, cannot be started until the system is mostly functional, towards the end of December.

F. HIGH DENSITY CONDUCTOR PATTERNS

Background:

Fine line-width conductors and spaces are essential for high density MCMs. For manufacturability of low cost MCM-Cs with such high density of interconnects, lines and spaces in particular, it is necessary that the screen printing process be continuous without interruptions in order to increase throughput. However, owing to the nature of printing fine lines, screens with fine intricate patterns get clogged during the printing operation due to various reasons, such as drying of the ink, introduction of unduly large particulates into the ink, etc. To counter this problem, manufacturers of screen printers allow for a 'swipe' cleaning of the screens after every 10 printing passes or so, such that the throughput remains high and at the same time clogging of the screens can be avoided.

Objectives:

- Develop a simple, robust, cost effective and manufacturable process for successful repeated screening of fine lines and spaces (a minimum of 4 mil wide lines and 4 mil space between them) of conductor lines for the LTCC-M based high density MCM-Cs.
- Demonstrate the reliability of test structures having 4 mil lines, spaces, and vias.

Major problems to solve:

- Formulate inks that will reduce fast drying of the inks on the intricate patterns on the screen and also prevent clogging of the screens.
- Optimize the conductor printing process such that at least 10 screen printing passes can be made before the screen needs wiping.

Approaches to solve the problems

A large number of experiments were designed and conducted during the course of the past two quarters. Experimentation involving the test structures mentioned in the last quarter was utilized to further evaluate Ag-based conductor inks. FLS-14 ink (top conductor ink) , that gave the best results for printing fine lines, was chosen for further optimization. It was surmised that the solvents used to make the resin components in the ink might be drying out during the course of printing. After half an hour of printing, whereby about a dozen parts were printed, the screen was plugged and needed cleaning.

Experiments were conducted by replacing, in part or whole, the solvent (terpeniol & butyl carbitol) in VC-1 and VC-2 resins by solvents that have high boiling points and low vapor pressures at ambient. Solvents explored included benzyl acetate, benzyl carbitol and dodecanol. Amongst the three solvents, dodecanol gave superior results. The final ink chosen was, FLS14-VC-108, which comprised of a resin VC-108, which in turn is a combination of one to one by weight ratio of VC-1 and VC-2, with all the terpeniol replaced by dodecanol. This ink could be printed successfully for several hours in a row without any apparent problem. The evaluation of printed conductors using the FLS-14-VC-108 ink that were subsequently fired test structures revealed that 0.003" wide lines with 0.003" spaces (20 pairs, > 2.0" long) could be successfully fabricated for all iterations. Also, most of the 0.002" wide lines with 0.002" spaces tested good in terms of continuity. Another ink, FLS-100, was also formulated using the same silver as in FLS-14-VC-108 with the elimination of all of the glass powder; this can be used as a buried conductor ink. Also, 0.003" wide lines with 0.003" spaces (20 pairs, > 2.0" long) could be successfully fabricated for all iterations.

Summary of Results

It is noted that the best screen printing results were obtained for the ink (FLS-14-VC-108) which had a finer particle size of the added glass, had no silver flakes and had an inorganic to organic ratio of 71:29 on a weight basis, with solvents having a high boiling point and lower vapor pressure. Fabrication of 0.003" wide lines with 0.003" spaces (20 pairs, > 2.0" long) was successful for all iterations; this can be considered state-of-the art in thick film fine line printing technology.

G. PLAN FOR NEXT QUARTER

- Fabricate high density test structures (4 mil lines, spaces and vias), using the fine line conductor printing inks that have been optimized during the previous two quarters.
- Begin reliability testing of 4 mil test structures made with the better printing ink formulations
- Fabricate a BGA package by combining results of the LTCC-M Customization Tasks
- Demonstrate robot-assisted singulation of green tape and part placement technique

Section III
WBS Task 2.3: Fabrication and Testing of Technology Demonstration Modules

A. TASK OBJECTIVE

The objective of this task is to design, fabricate, assemble, and test 4 different technology demonstration modules. These modules are: (1) an optoelectronic transceiver module, (2) a power amplifier package, (3) an advanced PCMCIA card, and (4) a Power Electronic Building Block (PEBB).

B. INTRODUCTION

The four technology demonstration vehicles planned for this program were chosen because each module had clear military applicability, and also met the requirements of the consumer marketplace. Table III.1 shows the application of each demonstration module to the needs of the US armed forces.

Table III.1:
Military Relevance of LTCC-M Technology Demonstration Vehicles

Prototype Application	Supporting Co.	Type	Military Relevance
Advanced PCMCIA Card (ORBCOMM Modem)	Torrey Science	Mixed Signal Module	1. Similar electronics needed for global tracking of high value and critical military materials and components (e.g. armaments) 2. Supports DoD: • Materials Command • Logistics Command • Transportation Command • "Total Asset Visibility" program 3. Technology applicable to the following: • NSA (R2) dual function PCMCIA card • Trackers • Message Terminals • CESEL • Special Forces replacement of high frequency radio systems (miniaturization) • Global extension of communications in Force 21 "Digital Battlefield" 4. Applies to Military Global Mobile Information Systems
High Power Motor Controller (Power Electronics Building Blocks)	Harris	High Power Single Chip Package	1. Supports US Navy Contract # N-00024-94-C-4088 (an Advanced Tech. Demo. with Naval Sea Systems Command) 2. Computer controlled Integrated Variable Speed Electric drive for ships (surface and subsurface) and tanks 3. Computer controlled Electric Actuators for airplanes, ships, and tanks 4. Auxilliary Power Unit Generators, Solid State Power Controllers for airplanes 5. Power Inverters and Converters for ships and airplanes
Optoelectronic Transceiver Module	AMP	MCM	1. Supports the construction of low cost broadband networks at military bases and installations. 2. Such networks support: • ATM based switching architectures • Transfer of large amounts of graphical and multimedia data • Digital signals • Encrypted signals 3. Supports ARPA contract "Manufacturable Low Cost Single-Mode Bi-directional Links for Fiber in the Loop Optical Networks" • Currently LTCC-M is the sole technology for this application
Power Amplifier Packages (microwave)	Raytheon	GaAs single chip package	1. Portable government cellular communications systems and wireless LANs 2. Applies to Military Global Mobile Information Systems

C. ADVANCED PCMCIA CARDS

Design

Torrey Science has completed the design of the RF Modem Module and has sent the circuit layout data to Sarnoff for substrate fabrication. Some key features of the design are:

- The design is based on an extended PCMCIA Type II card format.
- This is a 2-sided module with digital circuitry on one side of the LTCC-M substrate and the RF circuitry on the other side.
- Interconnections between the digital and RF circuitry are provided by means of insulated feedthroughs in the Cu/Mo/Cu metal core.
- Interconnections within the digital circuitry are provided by means of a 6-layer multilayer construction. The RF side consists of four ceramic layers.
- The design utilizes entirely surface mount devices and packages, bare dies (total of 16), and surface mount connectors for external connections.

The device outlines and surface metallization for each side, and the feedthrough holes in the metal core are schematically represented in Figures III.1 through III.5

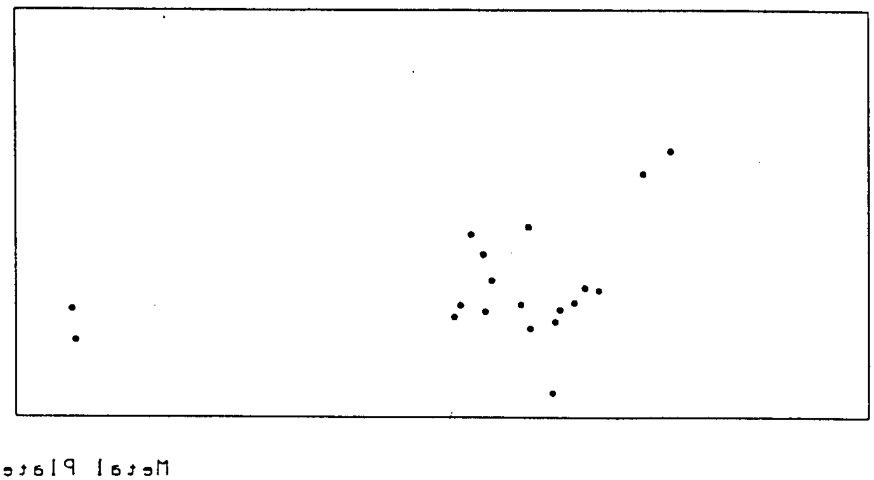

Figure III.1: *Outline of metal core and feedthrough locations.*

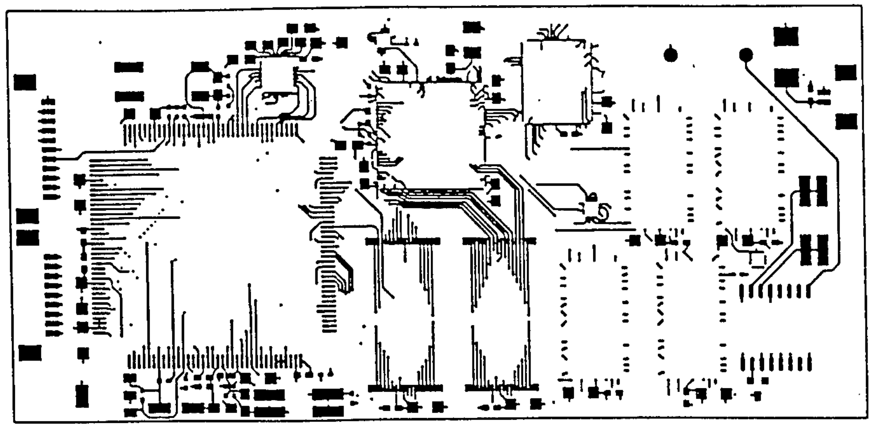

Figure III.2: *Digital side top surface metallization including interconnects, solder pads, and bonding pads.*

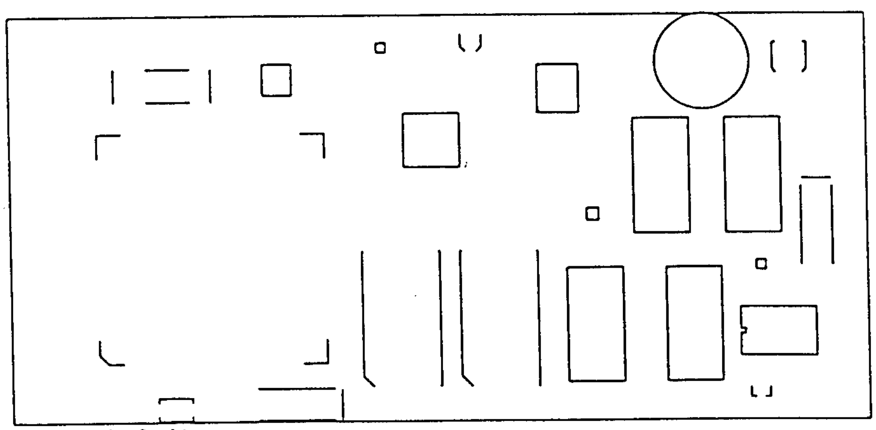

Figure III.3: *Outline of major devices on the digital side.*

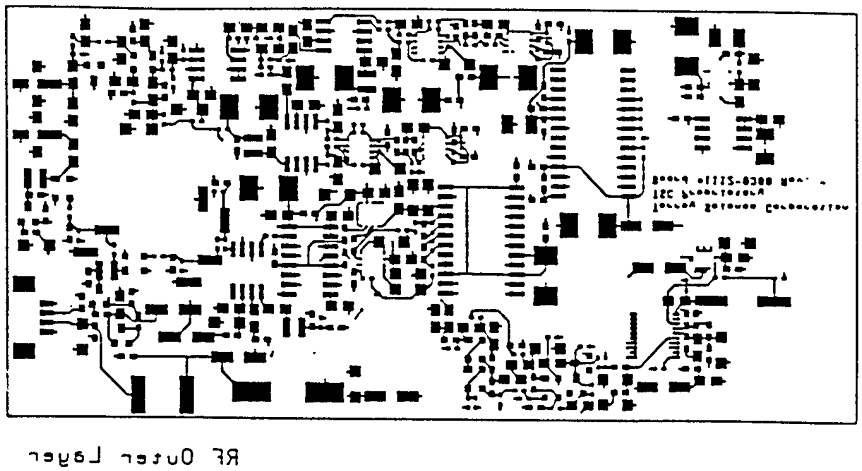

Figure III.4: *RF side top surface metallization including interconnects, solder pads, and bonding pads.*

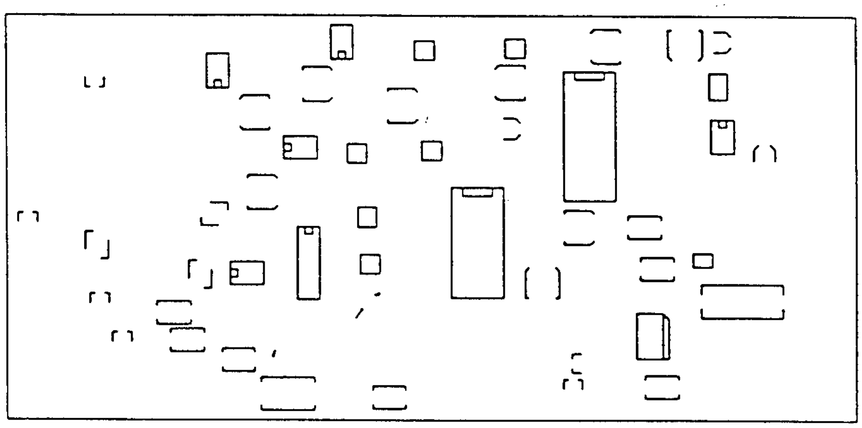

Figure III.5: *Outline of major devices on the RF side.*

Double-sided Substrate Fabrication

The design data from Torrey Science were converted to various fabrication tools by Sarnoff and the following tooling and services have been received this past quarter:

- Via punch files have been supplied to the tool and die vendor for building dedicated tooling for punching vias in the ceramic tape. A total of five die sets consisting of a blanking die, two via punch dies for the digital side, and two via dies for the RF side have been received. One punching die set was improperly made, and had to be sent back to the tool and die vendor for correction.

- Gerber files of the various layers of circuitry with alignment keys were supplied to printing screen and stencil suppliers, and all screens have been received A number of screens required corrections and were remade. The primary cause of these problems was incompatibility of the printed circuit board design software and the screen making software (compatible with the design software used by the multilayer ceramic and hybrid industries) used by the suppliers.

- Additional layers of artwork (that are not part of the Torrey Science design package) needed for LTCC-M construction, such as glaze layers, contact metal pads layers, and stabilization layers were also supplied to the screen vendor and all screens have been received.
- Algorithms were developed to convert the netlist files supplied by Torrey Science into files acceptable to Circuitest (Nashua, NH) for bare board testing. All test files have been completed and run properly on the test equipment at Circuitest.

While it was delayed by late delivery of all required tooling and design software incompatibility problems, the substrate fabrication process began this past quarter. Due to design complexity, the entire substrate fabrication process is rather lengthy and requires careful tracking throughout the fabrication process. Travelers were developed to track the prototype parts through a 27-step metal core fabrication process and a 38-step process for punching and screen printing the green tape through the lamination, cofiring and final electroless plating steps.

Once tested, Torrey Science will assemble the substrates with surface mounted components. The substrate is 2.13" x 4.5" with a Digital side and an RF side. Although the design calls for 6-layers of ceramic on the digital side and 4-layers on the RF side; 6-layers of tape are being used on both sides to balance the system during cofiring, thereby obtaining flat cofired parts. The board has (20) feedthroughs in the metal core which connect the RF and Digital sides; the first two sets of metal cores processed through the 27-step process had functional feedthroughs (good continuity and no shorting of feedthroughs to the metal cores).

The parts are being fabricated using The ABT-52 green tape and previously developed ink materials for both the metal core and green tape processing; however, slight modifications were made to the organic vehicles for several of the inks to improve their printing characteristics. The green tape is processed as 5"x5" blanks, which are punched with 8 mil diameter via holes using hard tooling. The via ink and buried conductor inks are Ag-powder based and a AgPd based ink is being used as the top metallization, over which Ag pads are printed for wire bonding. LN-1 ink is printed around the perimeter of each top layer, which serves to prevent the formation of a lip at the ceramic outer edges. After cofiring, the excess metal core at the periphery of the double-sided boards is removed by saw cutting, followed by cleaning, surface polishing and electroless plating.

The first set of four (4) double-sided substrates were fabricated and sent out for bare board testing. This first set of boards showed a number of shorts and opens; these problems must be corrected before module assembly can begin. However, the results were still quite encouraging. A first analysis of the bare board test data indicate that both via integrity and the top conductor connections are good, and are not the principal cause of the opens that were observed. It is suspected that layer misalignment during the stacking of the green tape layers is causing both the shorts and opens. A new stacking fixture with much tighter tolerances has been designed and is presently being built in the Sarnoff Model Shop. After completion, a new set of double-sided substrates will be fabricated and sent out for bare board testing.

Module Assembly

Torrey Science has selected CTM, Microelectronic Packaging, Inc. (San Diego, CA) as the module assembler. Some test parts were fabricated and sent to Torrey for wire bonding tests prior to fabricating the first prototype parts. Good results were obtained when wire bonding to the electroless Ni/Au plated Ag pads.

Issues

A number of factors have caused delay in this part of the program, making the remainder of the schedule very tight:

1. Difficulties in the procurement of needed components, especially bare dies, led to delays in completing the design by Torrey Science.
2. Design software differences between Torrey Science and Sarnoff have led to delays in procuring substrate fabrication tools at Sarnoff.
3. Design and fabrication of highly precise stacking fixtures for 5" x 5" green tape have delayed substrate fabrication.

All of these issues have been resolved and intensive effort is being put into fabricating substrates (that pass bare-board testing) for assembly and evaluation by Torrey Science.

D. PLAN FOR NEXT QUARTER

Optoelectronic Transceiver Module

- AMP to procure properly sized ASICs
- Module assembly by AMP
- Module evaluation by AMP

Power Amplifier Package

- Technical Demonstration Module is complete

Advanced PCMCIA Cards

- Complete substrate fabrication
- Complete assembly and test of module by Torrey Science

Power Electronic Building Blocks

- Fabricate substrates according to revised design by Harris
- Complete module assembly by Harris
- Complete module evaluation by Harris

Section IV
Important Findings

A. TECHNOLOGY TRANSFER TO MERCHANT SUPPLIERS

- All technology transfer training sessions were completed.
- The metal preparation process has been successfully implemented at DLI.
- Significant progress made in manufacturing acceptable green tape at R.E. Mistler, Inc. Additional optimization being conducted.
- Most of the thick film inks manufactured at Heraeus Cermalloy were judged acceptable. Additional work is being conducted to make the complete set of manufactured inks acceptable.
- Significant progress has been made in establishing the proper belt furnace profiles at DLI.
- The electrolytic Ni/Au plating process has been successfully implemented at DLI.

B. CUSTOMIZE LTCC-M FOR SPECIFIC APPLICATIONS

- Optimized a thick film ink for screen printing fine lines (3 mil lines and spaces). This can be considered to be a state-of-the-art thick film printing.
- Embedded cavity structures have been made in LTCC-M test structures. Internal vapor pressure testing indicates that these cavities are hermetic. Such cavities may function as resonant cavities in microwave module designs.
- Solder ball adhesion testing of 9 and 20 mil pads indicates that LTCC-M technology is compatible with the requirements of ball grid array (BGA) packages
- Robot arm has been received and installation is proceeding.

C. FABRICATION AND TESTING OF TECHNOLOGY DEMONSTRATION MODULES

- Completed fabrication of the initial set of RF Modem PCMCIA Cards. Bare-board testing of this lot indicates proper alignment between tape layers is critical for electrical continuity.
- Precise stacking fixtures have been designed and are being constructed for the fabrication of the second set of Advanced PCMCIA Cards.

Section V
Significant Developments

Based on the highly successful evaluation of the C-Band Power Amplifier Technology Demonstration Vehicle, Raytheon has submitted a bid to have a PCS Transceiver Module built in LTCC-M technology under the DARPA Mixed Signal Program.

Section VI
Plan for Further Research

TECHNOLOGY TRANSFER TO DIELECTRIC LABORATORIES INC.

- Evaluate the impact of peak firing temperature on both camber and the electrical properties of the tape
- Evaluate the impact of lamination pressure and temperature on the camber of the tape fired on to the core
- Optimize the next lot of tape from Mistler
- Evaluate the next lot of Heraeus thick film inks
- Build and test 20 samples of the Microwave Power Amplifier Technology Demonstration Vehicle
- Build and test 2 samples of LTCC-M with feedthroughs

CUSTOMIZE LTCC-M FOR SPECIFIC APPLICATIONS

- Fabricate high density test structures (4 mil lines, spaces and vias), using the fine line conductor printing inks that have been optimized during the previous two quarters
- Begin reliability testing of 4 mil test structures made with the better printing ink formulations
- Fabricate a BGA package by combining results of the LTCC-M Customization Tasks
- Demonstrate robot-assisted singulation of green tape and part placement

FABRICATION AND TESTING OF TECHNOLOGY DEMONSTRATION MODULES

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
Technical Report for: 9/15/96 to 12/14/96

4. TITLE AND SUBTITLE
Ceramic Metal Composite Circuit-Board-Level Technology for Application Specific Electronic Modules (ASEMs)

5. FUNDING NUMBERS
DAAB07-94-C-C009

6. AUTHOR(S) Dr. B.J. Thaler, Dr. A.N. Sreeram, Dr. E.S. Tormey, Dr. P. Palanisamy, Dr. M. Liberatore, Dr. T. Davis, Dr. T. Clark, and Dr. W. Vitriol

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
David Sarnoff Research Center
CN 5300
Princeton, NJ 08543-5300

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Sponsored by: Advanced Research Project Agency
Electronic Systems Tech. Office
Issued by: U.S. Army CECOM
Ft. Monmouth, NJ 07703

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Data Item
DI-MISC-80711

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The quarterly progress for the Ceramic/Metal Composite Circuit-Board-Level Technology for Application Specific Electronic Modules is described in this report. Data is reported for the following tasks: Technology Transfer to Merchant Suppliers, Customize LTCC-M for Specific Applications, and Fabrication and Testing of Technology Demonstration Modules.

14. SUBJECT TERMS

15. NUMBER OF PAGES
34

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	200 words

NSN 7540-01-280-5500

Standard Form 298 (rev. 2089)
Prescribed by ANSI Std. 239-18
298-102